AD-A044 292 NAVAL INTELLIGENCE SUPPORT CENTER WASHINGTON D C TRA--ETC F/G 1/3
THE INVESTIGATION OF TAKE-OFF AND LANDING CHARACTERISTICS OF JE--ETC(U)
JUL 77 V I SURUS

UNCLASSIFIED NISC-TRANS-3947 NL

| OF |
ADA
044292

END
DATE
FILMED
10-77
DDC

ADA044292

DEPARTMENT OF THE NAVY
NAVAL INTELLIGENCE SUPPORT CENTER
TRANSLATION DIVISION
4301 SUITLAND ROAD
WASHINGTON, D.C. 20390

3

CLASSIFICATION: UNCLASSIFIED

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

TITLE: (6) The Investigation of Take-off and Landing Characteristics of Jet Shortened Take-off and Landing Aircraft (STOL)

(K Voprosu Issledovaniya Vzletno-Posadochnykh Kharakteristik Reaktivnykh Samoletov Ukorochennogo Vzleta I Posadki (SUVP)),

(10)

AUTHOR(S): V. I. Surus V. I.

PAGES: 7

(21) Trans. of

SOURCE: Samoletostreniye I Tekhnika Vozdushnogo Flota No. 20, 1970, Pages 40-44 (USSR) n20 p40-44 1970.

DDC
RECEIVED
SEP 20 1977
B

ORIGINAL LANGUAGE: Russian

TRANSLATOR: C

(14) NISC-TRANSLATION NO.-3947

APPROVED P.T.K.

(11) DATE 25 July 1977

(12) 8p.

AD No.
DDC FILE COPY

407682 LB

THE INVESTIGATION OF TAKE-OFF AND LANDING CHARACTERISTICS OF JET SHORTENED TAKE-OFF AND LANDING AIRCRAFT (STOL)

V. I. Surus

The negative effect of secondary forces induced by the jet flow of the engine because of its ejection properties is not taken into account during the examination of aerodynamic and take-off and landing characteristics of jet STOL and VTOL aircraft (vertical take-off and landing aircraft) [1 - 6]. It can be so significant for certain STOL configurations (Figure 1) that aircraft equipped with a BLC system (boundary layer control) could be more preferable.

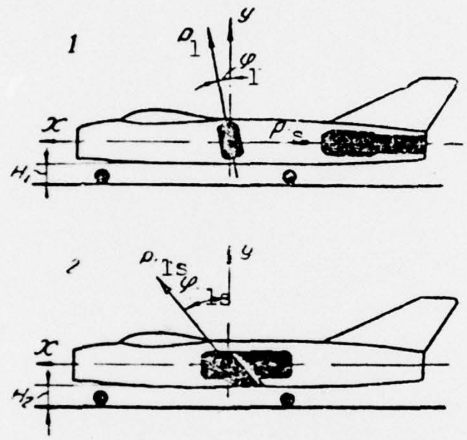

Figure 1. Diagrams of the examined STOL aircraft.

The question of the expediency of developing any particular types of aircraft, or, in any case, of identifying the boundaries of their expedient applicability arises. An exhaustive comparative analysis of these types of aircraft, including an analysis made from the viewpoint of take-off and landing and flight characteristics, as well as safety and economy is vital for this purpose.

This article examines an individual aspect of the indicated problem: the take-off run and take-off distances of the following hypothetical jet aircraft of the fighter type are compared (Figures 2 and 3), taking into account secondary forces characteristic for certain STOL configurations.

1. A conventional aircraft with a typical wing geometry is taken as the original: a swept or delta plane configuration, low aspect-ratio and high taper ratio, supersonic profile.

2. STOL aircraft with one lift engine having thrust P_1 and a sustainer engine

with thrust P_s mounted in the fuselage (diagram 1, Figure 1).

3. A STOL aircraft with one lift-sustainer engine with thrust $P_{1.s}$, mounted on the fuselage (diagram 2, Figure 1).

4. An aircraft with a conventional system of suction boundary layer control (SBLC) through a slot on the top surface of the slanted flap. This system has been used on series produced aircraft with TRD. According to statistical data, the lift coefficient C_y of such aircraft with the wing geometry specified in point 1 increases by approximately 0.25 with a 10% engine compressor air-bleed and thrust decreases by 15%. /41

5. An aircraft with an effective BLC system, for example, a combined system which combines the previous SBLC system with air extraction via a slot along the trailing edge of the wing. Such a system can ensure effective laminarization of flow around the entire wing and increase C_y by $\Delta C_y = 0.65$ with 20$ air-bleeding from the engine and a 20% reduction of its thrust.

We shall make the following assumptions.

1. Engine thrust of the examined aircraft changes according to take-off speed according to a law

$$P = P_0 - \frac{dP}{dV} V,$$

where P_0 is static thrust; $\frac{dP}{dV}$ = const - 0.1.

2. We average the values that depend on take-off run speed, including the secondary forces, and consider them to be constants in the process of the take-off run or lift, which gives an error of about 20% and is considered permissible when approximately estimating secondary forces.

3. Thrust losses, which are due to the intake of air contaminated with dust and the heated jet flow into the air intake [7], and also to turning of the jet flow [2, 7], comprise 8%.

4. Thrust vectors of the STOL aircraft lift and lift-sustainer engines tilted from the vertical, respectively, at angles ϕ_1 and $\phi_{1.s}$ (Figure 1), are constant during the take-off run (angle $\phi_{1.s}$ of aircraft 3 is 90° when climbing). Angle ϕ_1 has been chosen statistically and 12° [8], while $\phi_{1.s}$ was calculated [4] according to the formula

$$\cos \phi_{1.s} = \frac{P_{1.s}}{G}.$$

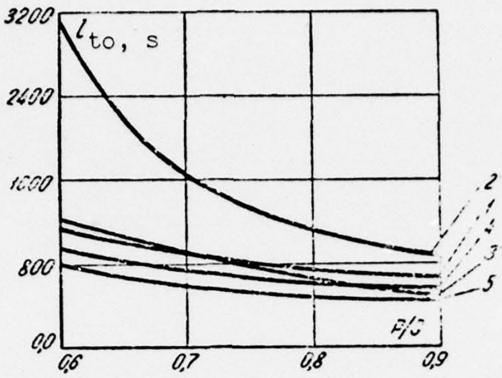

Figure 2. Relationships of distances of the take-off run l_r and the thrust-weight ratio of aircraft:
1, 2, 3, 4, 5 - compared aircraft.

5. The direction of thrust vectors of aircraft 1, 4 and 5 and thrust of the sustainer engine P_s of aircraft 2 coincides with the direction of motion.

6. We take coefficients C_x during take-off for aircraft 4 and 5 as for the original aircraft 1 because the SBLC system increases induced drag by decreasing form drag.

7. We shall consider an obstacle during take-off to be 15 m high.

8. The aerodynamic characteristics of the airframes of the compared aircraft and the thrust characteristics of engines are identical.

One can take into account secondary forces during the take-off run of the STOL aircraft (also similarly when climbing) in the following way:

$$C_{y_p} = C'_{y_p} - \Delta C_{y_p}; \quad C_{x_p} = C'_{x_p} + \Delta C_{x_p},$$

where C_{yp} and C'_{xp} are, respectively, the lift coefficient and drag coefficient during the take-off run without taking secondary forces into account.

The coefficients of lift reduction ΔC_{yp} and the increase of drag ΔC_{xp} /42
resulting from secondary forces must be determined experimentally because of the complexity of their mathematical interpretation. However, bearing in mind assumption 2, these coefficients can be calculated during approximate calculations according to the following approximate relationships, which were obtained on the basis of developing the theoretical and experimental works 2, 5, 9, 10 and are in satisfactory agreement with the experimental data:

$$\Delta C_{y_p} \approx k_1 \left(\frac{\bar{q}}{\bar{h}}\right)^2 \bar{S}; \quad \Delta C_{x_p} \approx k_2 \frac{\bar{q}}{\bar{h}} \bar{S}.$$

where $\bar{h} = \frac{H}{d}$ - ratio of the distance from the ground to the fuselage (Figure 1) to the diameter of the jet flow;

$\bar{q} = \frac{W}{V_{ar}}$ - ratio of the discharge velocity of the jet flow to the average speed of the take-off run;

$\bar{S} = \frac{S_{jet}}{S_w}$ - ratio of the cross-sectional area of the jet to the area of the wing;

k_1, k_2 - correction coefficients, which are functions of the angle of jet discharge $\phi_1(\phi_{1.s})$, the angle of attack of the wing α, the slant angle of the flaps δ_f, the slant angle of the elevator δ_e and other parameters.

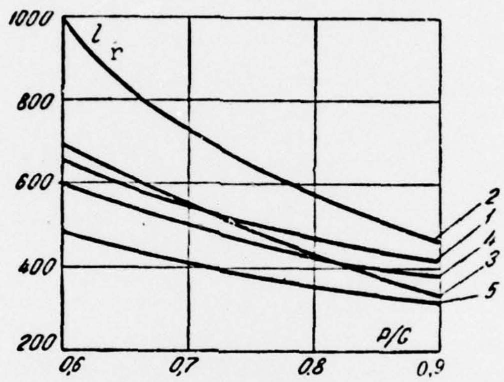

Figure 3. Relationships of take-off distances l_{to} and aircraft thrust-weight ratio: 1, 2, 3, 4, 5 - compared aircraft.

The cited relationships are valid for the examined STOL aircraft with a delta wing configuration and $\bar{h} \approx 0.9 - 1.2$.

Take-off distance was calculated according to the formula

$$l_{to} = l_r + l_1.$$

The length of the take-off run l_r was determined according to the formula

$$l_p \approx -\frac{1}{2A} \ln \frac{B - V^2_{otr} - Bv_{otr}}{B},$$

which is approximate, giving an error of less than 2% with solution of an integral of the type /43

$$l_r = -\frac{1}{A} \int_0^{V_{otr}} \frac{V}{V^2 + BV - B}\, dV.$$

which is obtained from the general expression for take-off run distance

$$l_r = \int_0^{t_{tr}} V\,dt = \int_0^{V_{tr}} \frac{V}{\dot V}\,dV.$$

From the equation of motion during the take-off run

$$\sum P_{i,x} = 0$$

one can determine acceleration

$$\dot V = A(C - V^2),$$

where

$$A = \frac{1}{2\bar p}\rho g\left(C_{x_p} - fC_{y_p}\right);$$

$$C = B - \mathrm{B} V.$$

For aircraft 2

$$C = 2\frac{P_{op}(\sin\varphi_1 + f\cos\varphi_1) + P_{os} - fG}{\rho S\left(C_{x_p} - fC_{y_p}\right)}; \qquad (1)$$

$$\mathrm{B} = 2\frac{0{,}1\,(1 + \sin\varphi + f\cos\varphi_1)}{\rho S\left(C_{x_p} - fC_{y_p}\right)}. \qquad (2)$$

For aircraft 3

$$\mathrm{B} = 2\frac{0{,}1\,(\sin\varphi_{1.s} + f\cos\varphi_{1.s})}{\rho S\left(C_{x_p} - fC_{y_p}\right)}, \qquad (3)$$

and one must substitute $P_{op.s}$ for thrust P_{op}, angle $\phi_{1.s}$ for angle ϕ_1, and thrust P_{os} is equated to zero.

For aircraft 1, 4, and 5, $\phi_1 = \phi_{1.s} = 90^\circ$, thrust P_{op} is assumed to be zero, and thrust P_{os} is substituted for thrust of the corresponding aircraft in expressions (1) and (3).

The distance of boosted lift with an obstacle height of 15 m is calculated according to the known formula

$$l_1 = \frac{1}{\frac{P_{av}}{G} - \frac{1}{K_{av}}}\left[\frac{V_1^2 - V_{otr}^2}{2g} + 15\right].$$

For example, we calculate the take-off characteristics of the above indicated hypothetical aircraft with the following data: aircraft weight G = 9600 kg; unit load on the wing $\bar p = \frac{G}{S} = 400$ kg/m^2; gravity acceleration g = 10 m/sec^2; air

density $\rho = 0.125$ kg/sec^2/m^4; friction coefficient $f = 0.03$ (dry concrete pavement); thrust weight-ratios of the aircraft $\bar{t} = 0.6; 0.7; 0.8; 0.9$; $\alpha_r = 2^\circ$; $\alpha_{otr} = 10^\circ$; $\delta_f = 45^\circ$; for aircraft 2, $k_1 \approx k_2 \approx k \approx 0.906$; for aircraft 3 value of k changes within limits of 0.25 - 0.68; $\bar{h} = 1.06$; $\bar{a} = 4$; $\bar{S} = 0.0236$; /44 the values of aerodynamic coefficients for the original aircraft are:

$$C_{y_p} = 0.55;\ C_{x_p} = 0.1;\ C_{y_{otr}} = 0.95;\ C_{y_1} = 0.67;\ C_{x_1} = 0.2.$$

The results of calculating the relationships of take-off run distances l_r and take-off distance l_{to} of the examined aircraft and the thrust-weight ratio $\bar{t} = \frac{P}{G}$ are given in Figures 2 and 3, on the basis of which one can draw the following conclusions.

1. Of the examined aircraft, aircraft 2 apparently has significantly longer take-off run and take-off distances. This is due to the negative effect of the jet flow, which creates a force opposite lift (secondary force) as the result of the discharge (ejection) of atmospheric air surrounding the aircraft.

2. If one does not take special measures, the effect of secondary forces can be so significant that aircraft 2 will possibly be worse even than the original conventional aircraft with respect to its take-off characteristics, not even to mention aircraft 5, equipped with an effective boundary layer control system.

3. During the investigation of take-off and landing characteristics of jet STOL aircraft of the separate configurations, one should take into account the effect of secondary forces which are ignored in many works, as was indicated at the beginning of the article.

4. It is vital to make an exhaustive comparative analysis of STOL aircraft and aircraft with modern promising boundary layer control systems on the basis of certain selective criteria in order to identify the boundary that shows when one should give preference to some particular type of aircraft.

5. It could be that the development of separate STOL designs that seem promising from the viewpoint of take-off and landing characteristics at first glance will prove to be generally inexpedient because of the advantages of aircraft with boundary layer control systems.

6. Aircraft 3 holds an intermediate position among the compared aircraft. It is slightly worse than the original aircraft up to a value of $\bar{t} \approx 0.7$, is equal to it at $\bar{t} \approx 0.7$, and is noticeably superior to aircraft 1 when $\bar{t} > 0.7$, and when

$\bar{t} > 0.8$ is even preferable to aircraft 4.

7. The problem of secondary forces, which is one of the many problems of creating STOL and VTOL aircraft, is quite complicated, particularly its theoretical aspect. Therefore it is vital to conduct profound theoretical and experimental investigations to solve this problem.

References

1. Tekhnicheskaya informatsiya BNI TsAGI, No. 22, 1966.

2. Tekhnicheskaya informatsiya BNI TsAGI, No. 1, No. 30, 1967.

3. H. Dathe. Zur Berechnung der Kurzstartleistungen von Flugzeugen mit Schubschwenk - Triebwerken. Zeitschrift fur Flugwissenschaften, No. 3, 1960.

4. G. Rotondi. Sulla corsoi die distasso dei velivoli a breve distanza die desollo (STOL) con trazione orientabile. "L'Aerotecnica", 1962, X, Vol. 42, No. 5.

5. K. Schwarzler. Die Entwicklung von Senkrechtstartflugzeugen in Deutschland. Jahrbuch, 1963 der WGLR.

6. Ekspress-informatsiya VINITI, seriya "Aviastroyeniye", No. 16, 1965.

8. A Manual on VTOL Aircraft. Trudy TsAGI, 1965.

9. W. Seibold. Untersuchungen uber die von Hubstrahlen an Senkrechstartern Erzeugen Sekundarkrafte. Jahrbuch, 1962 der WGLR.

10. O. V. Yakovlevskiy, A. N. Sekundov. Investigating Interaction of a Jet with Nearby Screens. Izv. AN SSSR. Mekhanika i mashinostroyeniye", No. 1, 1964.